SFOMC Task I: Oceanographic and Environmental Measurements

Alexander Soloviev
Nova Southeastern University Oceanographic Center
8000 North Ocean Dr.
Dania Beach, FL 33004
Phone: (954) 262-3659 Fax: (954) 262-4098 Email: soloviev@nova.edu

Robert H. Weisberg
College of Marine Science
University of South Florida
140 Seventh Ave S
St. Petersburg, FL 33701
Phone: (727) 553-1568 Fax: (727) 553-1189 Email: weisberg@marine.usf.edu

Mark E. Luther
College of Marine Science
University of South Florida
140 Seventh Ave S
St. Petersburg, FL 33701
Phone: (727) 553-1528 Fax: (727) 553-1189 Email: luther@marine.usf.edu,

Grant #: N00014-02-1-0950
http://www.nova.edu/ocean/, http://ompl.marine.usf.edu

LONG-TERM GOAL

The long-term goal of the project is to establish a real time physical oceanographic monitoring array for environmental data on the SFOMC Dania FL range necessary to support Marine Vehicle Tests and to assist with interpreting ocean acoustics experiments. In addition, the array will provide a test bed for the development of new technologies, and it will form a node in a larger, regional scale integrated coastal ocean observing system. These environmental data will also be valuable for understanding a variety of scientific questions that are important for the operation of an Acoustic Observatory to be built in the vicinity of the SFOMC Dania Beach, FL range during the next several years and for the conduct of fleet battle experiments.

OBJECTIVES

Our objectives are to further develop and maintain an environmental array for the purposes of:

- Supporting Marine Vehicle Demonstrations, acoustic experimentation needs, and other ONR-funded efforts; Continuing the real-time collection, archiving, and distribution of long time series to characterize the seasonal cycle and the seasonally modulated synoptic scale variability that determines the background environmental conditions for the SFOMC range;To perform analysis of the data collected in collaboration with other SFOMC investigators;To work toward the development of a node for a larger scale integrated coastal ocean observing system.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **SFOMC Task I: Oceanographic and Environmental Measurements**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Nova Southeastern University Oceanographic Center,,8000 North Ocean Dr.,,Dania Beach,,FL, 33004**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goal of the project is to establish a real time physical oceanographic monitoring array for environmental data on the SFOMC Dania FL range necessary to support Marine Vehicle Tests and to assist with interpreting ocean acoustics experiments. In addition, the array will provide a test bed for the development of new technologies, and it will form a node in a larger, regional scale integrated coastal ocean observing system. These environmental data will also be valuable for understanding a variety of scientific questions that are important for the operation of an Acoustic Observatory to be built in the vicinity of the SFOMC Dania Beach, FL range during the next several years and for the conduct of fleet battle experiments.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

NSU and USF maintain a mooring array as a part of SFOMC in coordination with the acoustic experimentation and other ONR activities in the area. The array consists of surface and bottom moorings with acoustic Doppler current profiler (ADCP) and a combination of inductively coupled and/or self-recording SeaBird Electronics sensors. The bottom mooring is equipped with an upward looking ADCP and an SBE-26 CTD. The bottom instruments work in self-recording mode (pending connection to the SFOMC MUX). The ADCP has been upgraded with the RDI Wave Package that is to be activated after connection to the MUX. The Environmental Array, deployment schemes, and data acquisition software are developed at the USF College of Marine science and the NSU Oceanographic Center.

WORK COMPLETED

The project (previously through a FAU/ONR subcontract) is on its fifth year. Details relating to the accomplishments associated with the field intense efforts in years 1-4 of the program have been summarized in earlier reports. These include the following accomplishments. The NSU/USF Environmental Array was acquired, tested, and then deployed in different configurations, depending on the SFOMC needs and situations. Elements of the array have been collecting data since June 1999. These array elements consist of buoys and bottom moorings with acoustic Doppler current profilers (ADCP) and a combination of inductively coupled and/or self-recording temperature/salinity sensors. A meteorological tower was also deployed on the Dania Beach Pier on several occasions. The Environmental Array provided data in support of the FAU Adverse Weather, 4-D, and US Navy Fleet Battle Experiments in 1999 and 2000. Soloviev et al. (2001) report on the data collected during the first two years. The data sets have been organized into a database, which is published on CDROM by NOAA/NODC. Scientific results of the project were presented at several national and international conferences, most recently at the IUGG 2003 General Assembly in Sapporo, Japan, June 30 – July 11, 2003 (Soloviev et al., 2003b). Several technical and scientific papers have been published that included the data obtained with the environmental array (Luther et al., 2001; Shay et al., 2000; Shay et al., 2003; Soloviev et al., 2003a; Soloviev et al., 2003b).

During FY03 (1 October 2002 – 30 September 2003) the environmental array was deployed in support of SFOMC acoustic experimentation. Owing to modifications to the original SFOMC plan and overall delay with the field phase, we modified our program to synchronize it with the new schedule. The surface mooring was deployed at a 20m isobath in May 2003. It contains a downward looking ADCP, which provides the current velocity profile at 1m vertical resolution and SBE-37 MicroCat instruments installed at three depths between the near surface and near bottom. The ARGOS satellite network is used to monitor the surface mooring position. The 11m isobath bottom mooring contains an upward looking ADCP and SBE Wave Gauge. The ADCP provides a current velocity profile at 0.5m vertical resolution; the Wave Gauge measures temperature, conductivity, sea level, significant wave height, and surface wave spectra. This mooring is designed to transmit data via the SFOMC MUX and also stores data internally. The data are presently stored internally. The junction box connecting a 2000 ft cable with the moored instruments was modified (by the SFTF technical personnel) to accommodate recent modifications of the MUX wiring. The ADCP instrument was upgraded with the RDI surface wave package and is now pending connection to the MUX. The Dania Pier meteorological station was supported from the project for approximately one half year. It is presently inactive.

As of September 2003, the Environmental Array continues the data collection in support of the SFOMC acoustic experiment.

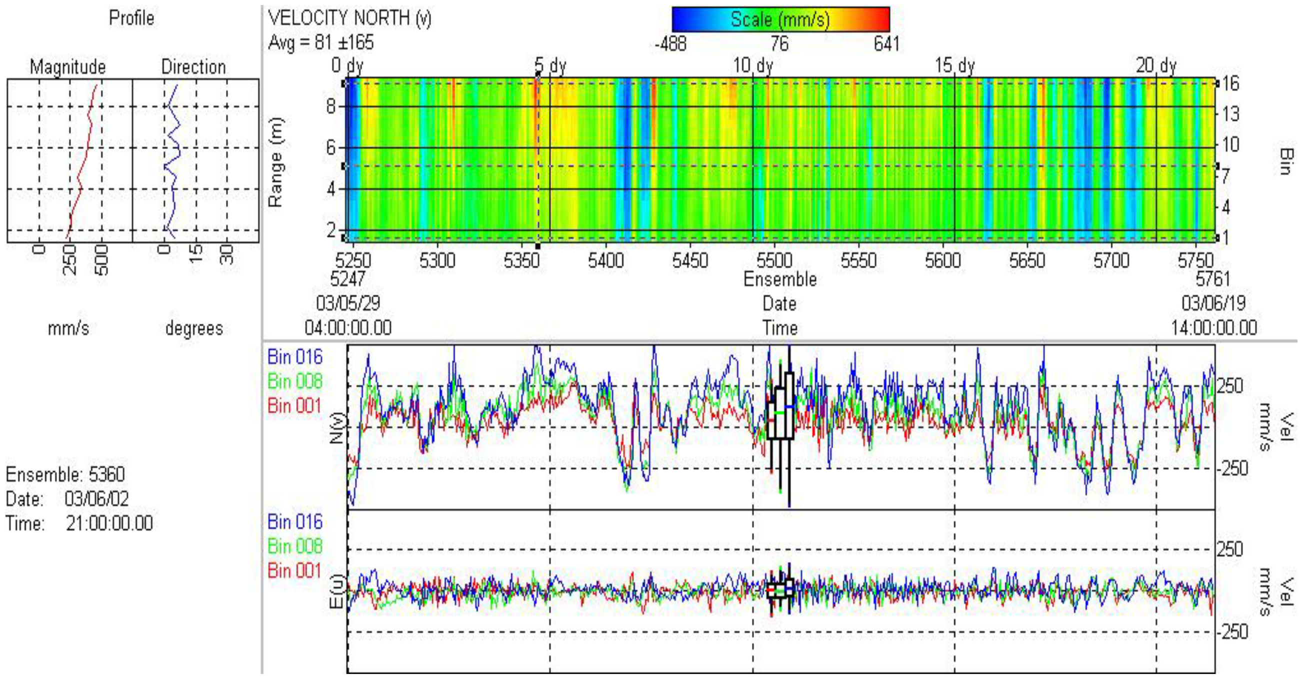

Figure 1. Current velocity variability in the SFOMC range (11-m isobath mooring) from May 3 to June 19, 2003

Data analyses on the full data set for the years 1999-2003 are continuing. A paper describing the variability of the coastal circulation on the shelf off southeast Florida is published (Soloviev et al., 2003.). As of the end of September 2003, the field stage of the SFOMC acoustic experiment is in progress, and the Environmental Array continues to collect data, although not in real time since the MUX is not operational.

RESULTS

The SFOMC data set obtained with the Environmental Array during the first four years of observations demonstrates the characteristic features of the coastal circulation on the shelf off southeast Florida. Along with tides and synoptic weather induced currents we observe strong modulated baroclinic velocity fluctuations at both super-tidal to sub-tidal frequencies. The spectral analysis of the summer 1999 velocity record revealed oscillations of ~0.5ms^{-1} amplitude with a super-tidal 10hr periodicity (Soloviev et al., 2003). Unlike the currents the sea level record showed a more characteristic semi-diurnal tidal peak. This 10hr peak was observed at all locations (11m, 20m, and 50m isobath moorings), although at lower frequencies, the velocity spectra diverged (with stronger signals on the 50m mooring location and a weaker signal on the 11m location). The velocity signal was accompanied with coherent density variations, which confirmed that the observed oscillations were of baroclinic nature. During the next summer (Year 2000), the supertidal oscillations were not as prominent. The oscillation restored during the summer of 2001 and 2002 (though weaker than during summer 1999).

Presently ongoing are analyses of the modulation both in frequency and time of these super- and sub-tidal oscillations. An initial crude exposition of the super-tidal range is shown in Figure 2 as spectral energy time series in a band covering 8 to 12.5 hr periodicities. Seasonal and interannual variability is observed with summer months being more energetic than winter months. Differences from year to year are also prominent. By convolving variable frequency waveforms through the record we are generating amplitude and frequency distributions as a function of time over a broader super to subtidal bandwidth to more fully describe the observed properties. Preliminary analyses are complete and will be reported on later this year.

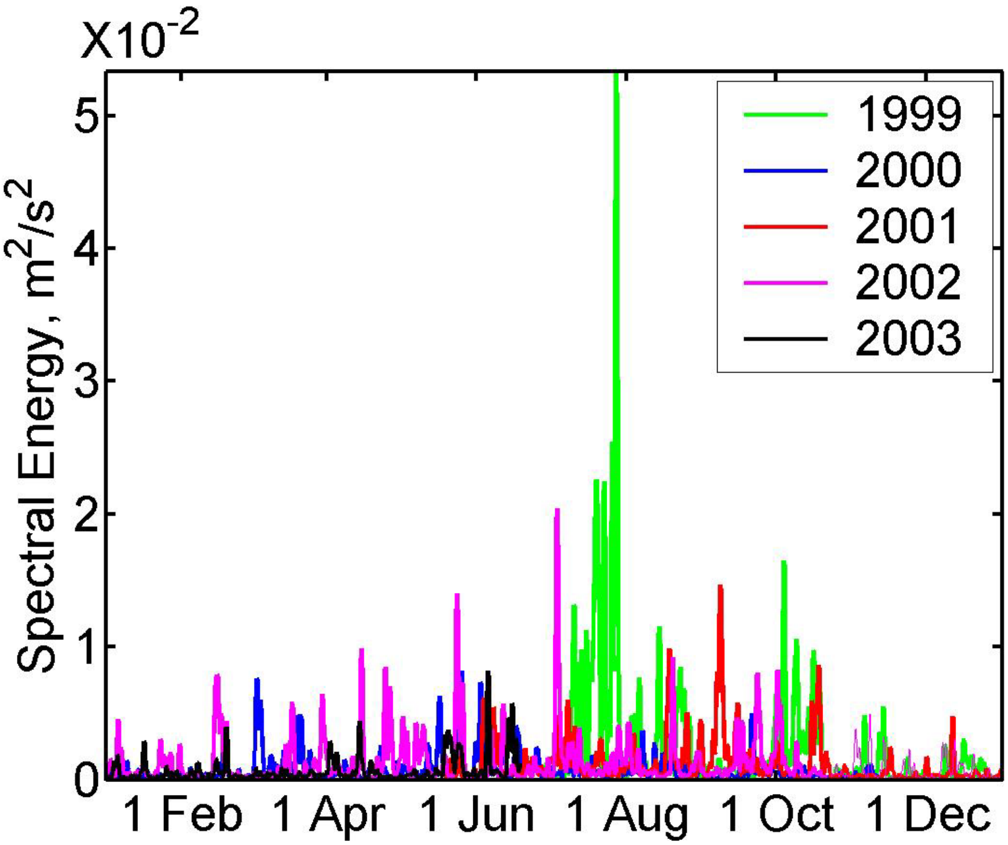

Figure 2. Seasonal and interannual change of the spectral energy of the velocity oscillation within the 8 to 12.5 hour band (NW bottom mount at 11-m isobath)

Bathymetric cross-sections of the Florida Straits at the latitude of the SFOMC range reveal an abrupt change of the channel depth at a 30-km distance from the Florida coast. Such change in depth (the Miami Terrace) at the edge of the continental shelf is an important factor in the exchange of energy between the surface and internal wave modes (Niiler, 1968). A cross-channel baroclinic tidal oscillation could be excited by a surface tidal wave traveling along the non-uniform channel. The baroclinic oscillation may become large if the period of the surface tidal wave is close to the natural period of an internal seiche in the channel. A factor determining the “resonant” properties of the Florida Straits is the vertical density stratification; in particular, the position of the Gulf Stream front with respect to the continental shelf break. From Niiler’s equation, an estimate of the natural period of an internal seiche in the Florida Straits at 26^{o}N, is $T_s \sim 10$ hrs. The SFOMC data, covering a 4-year time period (1999-2002), are consistent in general features with the hypothesis of a resonant cross-stream internal seiche. In particular, this mechanism can explain the observed modulation on seasonal

time scales as the dependence of the channel resonant properties on the stratification and the position of the Gulf Stream. A more sophisticated analysis (yet to be done) should show generation of internal tidal waves on the three-dimensional bottom topography. Our preliminary estimates indicate that topographical features associated with the first and second reef tracts can also radiate rays of M_2 internal tides. The seasonality and interannual variability seen in Figure 2 can hence be attributed to changes in stratification, location of the Gulf Stream and the importance of these changes on the internal seiche. Spin-off eddies, observed off the southeast Florida shelf can also modulate the upper ocean layer depth and the internal seiche period over time scales of about 10 days or less.

The fact the supertidal oscillations can be so energetic is intriguing because it may provide another, entirely different source of the energy dissipation for the Gulf Stream that may act in concert with the spin-off eddies, as well as providing energetic forcing for cross-shelf and vertical mixing. The velocity scale of the baroclinic supertidal oscillation is 0.5 m s^{-1}; while, the characteristic velocity scale of the barotropic tide on the southeast Florida shelf is of 0.05 m s^{-1}. Since the dissipation of the kinetic energy of currents is proportional to the cube of the current velocity magnitude, the arrival of the supertidal baroclinic oscillation can increase the tidal energy dissipation on the southeast Florida shelf as much as by three orders of magnitude.

Though internal seiching is a plausible explanation for the super-tidal oscillation observed on the shelf off southeast Florida, two other hypotheses cannot completely be rejected. The first of these considers the substantial relative vorticity associated with the Gulf Stream. The inertial peak could be shifted to a higher frequency due to vorticity. Substantial relative vorticity associated with the Gulf Stream has been reported in many studies (Rossby and Zhang, 2002). Mooers (1975) suggested that the effective local inertial frequency $\sigma_f = \left[f (f + \overline{v}_x) \right]^{1/2}$ (where *f* is the Coriolis parameter) maybe substantially reduced due to significant vorticity ($\overline{v}_x$) in the western boundary of the Gulf Stream. Average vorticity at the western boundary of the Gulf Stream in the Florida Straits (i.e., of the Florida Current) of 4*f* or higher have been reported in the SFOMC range (Peters et al. 2002). Such average vorticity can reduce the 27-hr inertial period to the 10-hr oscillation observed experimentally on the southeast Florida shelf. A narrowband character of the 10-hour signal observed during summer 1999 is, nevertheless, typical for tidal rather than eddy-related phenomena (Peters et al., 2002).

Another hypothesis suggests that the 10 hr peak could be the semidiurnal internal tide Doppler-shifted by the Gulf Stream (Luther et al., 2001). This hypothesis is based on an assumption that the velocity fluctuations in the coastal area can be induced by motions outside this area (for instance, by the nearby Gulf Stream). The intrinsic or Doppler-shifted frequency of a semidiurnal internal tide propagating southward through Florida Straits (*i.e.*, against the mean current) is estimated from Mooers' (1975) formula to be ~10 hrs. Peters et al. (2002), however, argue that if the internal tide is generated by the surface tide elsewhere on the continental shelf, "…in the environment of time-invariant, spatially variable mean current, the encounter frequency of any wave signal is conserved along rays (LeBlond and Mysak, 1978; equation 6.19b). It is only the intrinsic frequency, measured with respect to the fixed observer moving with the mean current, that is changed."

Continuing efforts hope to elucidate the physics leading to these energetic but seasonally and inter-annually modulated velocity fluctuation. In particular, numerical modeling might distinguish between the three proposed generating mechanisms as well as help to facilitate future observations in the most effective way.

IMPACT/APPLICATION

The observed variability in the coastal currents on the Southeast Florida shelf has impacts of both societal and Navy related. Order 0.5 ms^{-1} oscillations over relatively short periods of time will affect any maritime operation, either Navy or civilian, conducted within the region. Such currents were hitherto known to exist in the Gulf Stream and with spin-off eddies associated with the Gulf Stream, but these are something entirely different. Societal relevance includes safe navigation, search and rescue operations, beach erosion, coastal pollution from sewage plants, harmful algal blooms, and hazardous material tracking.

TRANSITIONS

This activity has created an effective infrastructure for the oceanographic support of Navy projects on the shelf off Dania Beach, FL. It also provides a basis for an eventual transition to an observational real time node as part of a larger scale, integrated coastal ocean observing system.

RELATED PROJECTS

The NSU/USF group has more than four years of nearly continuous observations on the shelf off Southeast Florida including several intensive observation periods in collaboration with the SFOMC groups from FAU, UM, and SFTF.

REFERENCES

Dhanak, M.R., E.P. An, and K. Holappa. An AUV survey in the littoral zone: small-scale subsurface variability accompanying synoptic observations of surface current. *IEEE Journal of Oceanic Engineering*, *26*, 1506-1518, 2001.

LeBlond, P.H., and L. A. Mysak, Waves in the Ocean, 602 pp. Elsevier Sci., New York 1978.

Mooers, C.N.K.: Several effects of a baroclinic current on the three-dimensional propagation of inertial-internal waves. *Geophys. Fluid Dynamics, 6*, 277-284, 1975

Niiler, P.N. On the internal tidal motion in the Florida Straits, *Deep-Sea Research*, *15*, 113-123, 1968:
Peters, H., L.K. Shay, A.J. Mariano, and T.M. Cook/ Current variability on a narrow shelf with large ambient vorticity, *Journal of Geophysical Research, 107***,** 2002

PUBLICATIONS IN RESPONSE TO THE PROGRAM

Luther, M E., Soloviev, A.V., and R.H. Weisberg. Internal Tides Doppler-Shifted by Gulf Stream. The Oceanography Society Meeting, 2-5 April 2001, Miami Beach, Florida USA. Abstract published in *Oceanography*, *14*, No. 1, p. 35, 2001 [published].

Shay, L.K., T.M. Cook, B.K. Haus, J. Martinez, H. Peters, J. VanLeer, A.J. Mariano, P.E. An, S. Smith, A. Soloviev, R. Weisberg, and M. Luther, 2000: VHF Radar detects submesoscale vortex along the Florida Coast, *EOS*, 81, 209-213 [published, refereed].

Shay, L. K., T. M. Cook, H. Peters, A.J. Mariano, R.H. Weisberg, P. E. An, A.V. Soloviev, and M.E. Luther, 2002: Very high-frequency radar mapping of surface currents, *IEEE Journal of Oceanic Engineering*, *27*, 155-169 [published, refereed].

Soloviev, A.V., M.E. Luther, and R.H. Weisberg, 2003a. XXIII General Assembly of the International Union of Geodesy and Geophysics, IUGG, June 30-July 11, 2003, Sapporo, Japan [published]

Soloviev, A.V., M.E. Luther, and R.H. Weisberg, 2003b: Energetic baroclinic super-tidal oscillations on the shelf off Southeast Florida, *Geophysical Research Letters*, 30, No. 9, 1463, doi:10.1029/2002GL016603 [published, refereed]

Soloviev, A.V., Thompson, T.L., Nemeth, L., Campbell, C.B., Weisberg, R.H., Luther, M.E., Cole, R., and J. Donovan, 2001. "Data Report, NSU Oceanographic Center and College of USF marine Science", Report #2001-1 (published by NOAA as CD, including the data report and the data base) [published]